THE FOOD OF CERTAIN MINNOWS

A STUDY OF THE SEASONAL DIETARY CYCLE OF SIX CYPRINOIDS WITH ESPECIAL REFERENCE TO FISH CULTURE

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Introduction

The smaller members of the family Cyprinidæ although often neglected, are without doubt the most important of the small fishes which inhabit our fresh waters. To the practical fish culturist they are of greater importance than is usually recognized since they represent the food of many game and food fishes, while their diversity of species and habits, together with their interesting ecological relations, and availability, make them of considerable interest to the scientific student. A study of their intimate relationships and habits, therefore, is at once important from an economic and scientific standpoint. With these considerations in mind, this study of the food and feeding habits was essayed, since they are undoubtedly among the chief factors in the lives of these fishes.

Fish Cultural Value

The fact of primary importance to fish culture is that these minnows enter largely into the diets of the larger game fishes. At least twenty-three different predatory fishes are known to subsist largely upon various cyprinoids. They are as follows:

Lepidosteus osseus (Linnæus)................Long-nosed Gar or Billfish
Hiodon alosoides (Rafinesque)...............Golden-eye or Northern Moon-eye
Hiodon tergisus Le Sueur.....................Golden-eye or Moon-eye
Pomolobus chrysochloris Rafinesque...........Skipjack
Salmo sebago (Girard).......................Sebago Salmon

Cristovomer namaycush (Walbaum)	Lake Trout
Esox americanus (Gmelin)	Little or Bonded Pickerel
Esox reticulatus (Le Sueur)	Pickerel or Pike
Esox lucius Linnæus	Pike
Esox masquinongy Mitchill	Muskallunge
Aphredoderus sayanus (Gilliams)	Pirate Perch
Pomoxis annularis Rafinesque	Crappie or Croppie
Pomoxis sparoides (Lacépède)	Black Crappie or Calico Bass
Ambloplites rupestris (Rafinesque)	Rock Bass
Chaenobryttus gulosus (Cuvier and Valenciennes)	Warmouth
Micropterus dolomieu Lacépède	Small Mouthed Black Bass
Micropterus salmoides (Lacépède)	Large Mouthed Black Bass
Stizostedion vitreum (Mitchill)	Wall Eyed Pike
Stizostedion canadense (De Kay)	Gray Pike or Sauger
Perca flavescens (Mitchill)	Yellow Perch
Roccus chrysops (Rafinesque)	White Bass
Roccus lineatus (Bloch)	Striped Bass
Morone americana (Gmelin)	White Perch

After listing a number of species (included above), Forbes and Richardson ('08), add: "That th's list might be considerably enlarged by more extensive studies of the food of fishes is beyond a doubt, and it is safe to say that no fish-eating fish would, if hungry for fish, refuse a minnow of any kind unless it seemed too small to be worth the trouble capturing. . . . Moreover, by their great numbers, by their various adaptations and corresponding ecological d'stribution, and by their permanently small size, the minnows must distract in great measure the attention of carnivorous fishes from the young of the larger species, upon which, without them, the adults of these larger species would fall with the full force of their voracious appetites. . . . It is not too much to say, consequently, that the number of game fishes which any waters can maintain is largely conditioned upon its permanent stock of minnows."

Since the successful stocking of any stream with game fishes depends upon the food supply, it is essential to know how this important item may be maintained. As Forbes ('83) remarked, "Really intelligent fish-culture on any large scale, implies a full acquaintance with the food of the native species."

Fortunately, most of our streams east of the Rocky Mountains seem to be plentifully supplied with Cyprinoids, numerous species being found frequently in one stream. The availability of these fishes as a staple food for larger fishes depends upon their abundance, which, in turn, depends upon the abundance of their food. It is important, therefore, to know what these minnows eat at various seasons of the year. For this reason a considerable portion of this paper is devoted to the analysis of the stomach contents of specimens taken at various seasons.

Scientific Value

Ecologically and taxonomically the Cyprinidæ form a puzzling group. A study of the affinities of the various species is needed, both with reference to anatomical details and environmental conditions. In this connection, a knowledge of the food of the group throughout the seasons is of prime necessity and the results embodied in this paper, it is hoped, may be of value to other workers.

Minor Values

This group of fishes furnishes a large per cent of the bait to fishermen, sport for many a small boy, and a few of the larger species are used for human consumption.

Any or all of the different species of suitable size may be used as bait, many being hardy as live bait, but *Notropis cornutus* is probably the favorite among most of the fishermen. *Semotilus bullaris* is a wary fish and in some localities, at least, it is regarded as a minor sport fish.

Lastly, many of the species, in fact all of those which were collected in connection with this work, are attractive aquarium fishes, most of them becoming adapted to balanced aquaria, although they become adapted more readily to conditions in an aquarium supplied with running water.

Field Methods

In order to determine the nature of their food, collections were made of six of the common species of cyprinoids occuring in the District of Columbia.

A small stream known as Oxon Run was chosen for this purpose because of its accessibility and various physical features which will be subsequently described. It was decided that collections should be made once a month for one entire year. This plan was followed, except that no collection was made in August, but the collecting dates were so arranged that the greatest gap be-

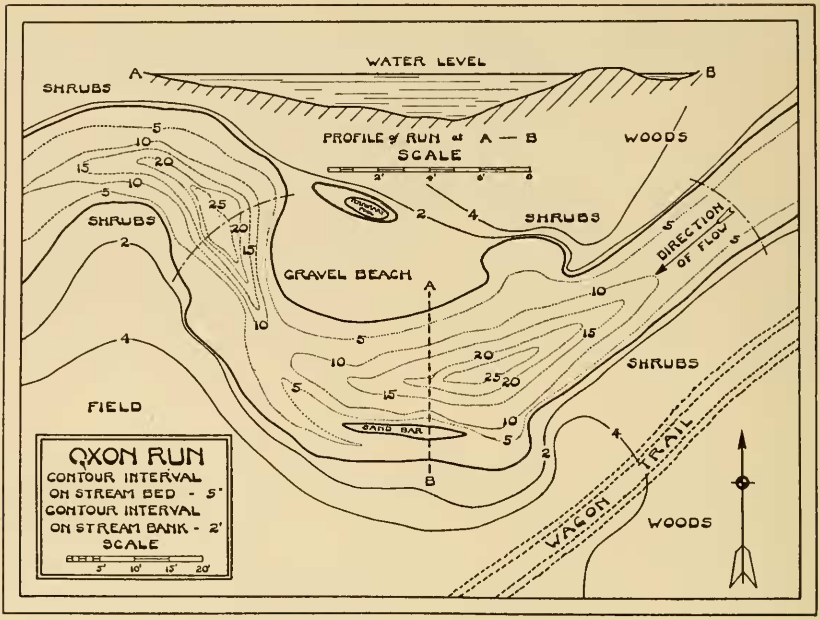

FIG. 98. MAP OF COLLECTING SITE

The two curved lines crossing the stream mark the limits of the area in which the collections were made. This locality is indicated on the Washington Biological Society's Map (MacAtee '18) as S. E. G. 12.

tween any two was only 49 days, which period spanned that month.

Oxon Run is about 7.5 miles long and flows into the Potomac River near the southeast boundary of the District, opposite Alexandria, Va. In every way it is a typical steam such as found in the coastal plain region of Virginia and Maryland. It was observed that there was a considerable fluctuation in the amount of flow, depending on the amount of rainfall, and consequently, the turbidity varied accordingly. These changes were not detrimental to the work, although the swift current increased the difficulty of hauling the seine. The location shown on the map (Fig. 98) is about 2¼ miles above the mouth and was chosen because there is a rather deep eddy, on one side of which is a small beach providing an ideal place for hauling out the seine. The bank opposite this beach is rather high with overhanging shrubs, grasses and other plants. Upstream, the channel is nearly flat and has a gravelly

TABLE NO. I

PHYSIOGRAPHICAL CONDITIONS AT OXON RUN DURING 1920

Date	Temp. (Fahr.) Air	Water	Condition of Water Turbidity, Etc.	Depth	Weather Conditions
Jan. 1	48	37	Rather swift, fairly clear	12 inches	Partly cloudy
Feb. 1	29	32	2 inch ice over area seined	Greatest, 36 inches	Snow flurries. Cloudy
March 14	42.5	38	Slightly murky	Evidence of previous high water	Fair and windy
April 11	59	58			Fair
May 23	..	63			Partly cloudy; warm
June 13	89	71	Clear	Quite low	Partly cloudy
July 17	80	74	Very roily from children swimming		Sunny; hot
Sept. 4	83	66	Very clear	Low	Clear or partly cloudy
Oct. 4	75	57	Very clear	Very low	Fair
Nov. 7	61	48	Clear	Low	Cloudy
Dec. 5	65.5	49	Turbid, swift	Highest noted	

bottom that slopes gently, the water being about six inches deep at the low water stages. Down stream there are deeper places which were found unsuitable for seining. The table of physiographic conditions (Table No. I.) shows the general conditions and seasonal variations under which the collections were made.

All of our collections were made within the limits shown on the map by means of a ten-foot seine of one-quarter inch mesh. The bottom was quite free from snags and weeds of any kind and the only cover provided for the fishes was such debris as dead leaves and other materials which may have collected in the eddy. Even when the water was clear, few fishes were to be seen, yet the number of specimens collected gives some evidence as to their abundance. No definite number of hauls was made, since the catch each time was found to vary considerably, collecting being continued until a sufficient number of specimens had been secured, or until the site had been exhausted temporarily of fish. The specimens were placed immediately into formal alcohol and sorted later in the laboratory. Formal alcohol was found to be an efficient killing fluid since it acted quickly thus preventing further digestion of the stomach contents and hardened the specimens without perceptible shrinkage.

Laboratory Methods

After the specimens were brought to the laboratory, the solution of formal alcohol was poured off and 75 per cent. alcohol substituted for permanent preservation. Each species was preserved in a separate bottle and the different monthly collections were also segregated. Each fish was measured, the standard length being recorded because this measurement was used in constructing curves of growth which are discussed further on. Since this is the only measurement referred to throughout the paper it is mentioned subsequently simply as length. Each specimen was provided with a paper tag numbered serially to provide a ready reference to each specimen. In all, there were 1554 specimens including six species.

The entire digestive tract of each specimen was removed and the contents pressed out on a glass slide. The material was examined with a low power of the compound microscope supplemented by higher powers when necessary. Pierce's method (Pierce '15)[1] was used to estimate the various quantities of food present. It is apparent that such a method can yield only a rough estimate, but none other was found to be feasible on account of the time required to make more accurate volumetric determinations. It is pointed out that frequently only small quantities of food, such as the leg of a beetle or wing of a fly, would be found yet such material had to be listed as 100 per cent. coleopterous, or dipterous remains, as the case might be, since there was no evidence of other food having been eaten. However, these errors would be naturally compensating rather than cumulative and in the tables we present giving the averages of each collection, they lose significance.

[1] Briefly, in this method the contents of each example is considered as unity, the various items being expressed in terms of percentage by volume as estimated by inspection.

FIG. 99. VIEW LOOKING UP STREAM

FIG. 100. VIEW LOOKING DOWN STREAM

In taking these photos the camera was located a little beyond the upper and lower limits, respectively, of the area in which the collections were made. Taken in early October. See Map, page 290.

FIG. 101. ENTIRE CONTENTS OF THE STOMACH AND INTESTINE OF A SPECIMEN OF *NOTROPIS CORNUTUS* 7.3 CM. IN LENGTH TAKEN IN DECEMBER. 4X

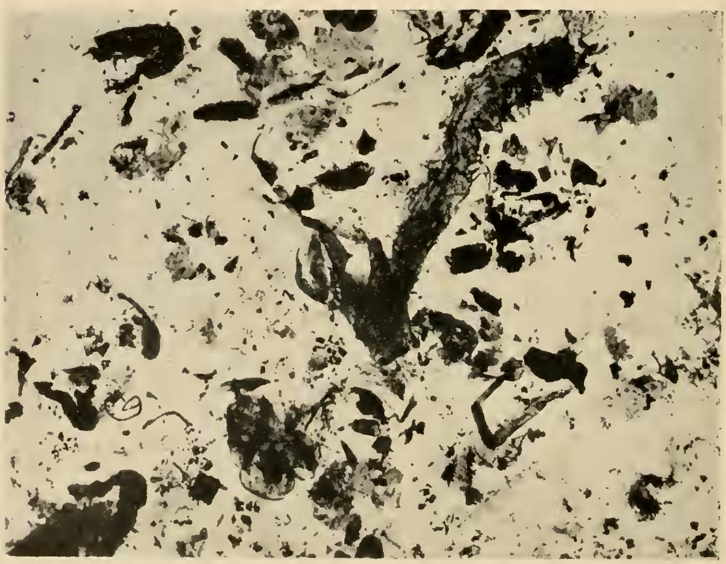

FIG. 102. ENTIRE CONTENTS OF THE STOMACH AND INTESTINE OF A SPECIMEN OF *NOTROPIS CORNUTUS* 5.7 CM IN LENGTH TAKEN IN DECEMBER. 4X

Photomicrographs showing the degree to which the food was usually found to be macerated.

The food was found to be masticated usually beyond the possibility of positive identification, as illustrated by figs. 101 and 102. This condition, doubtless, was caused by the action of the raptorial pharyngeal teeth possessed by these species. However, it was possible to distinguish insect remains from those of other organisms and often the various orders of insects such as Coleoptera, Diptera, etc., could be separated.

Our thanks are due Mr. J. T. Nichols, of the American Museum of Natural History at whose suggestion the problem was undertaken, to Dr. W. C. Kendall, of the U. S. Bureau of Fisheries, for determining the identity of certain specimens, and to Dr. R. E. Coker, for his kindness in allowing the use of the facilities of the Division of Inquiry of the latter institution. All illustrations have been made by the senior author.

Observations

Arrangement of Treatment by Species.—Complete statements and tables of the stomach contents of the six species on which this paper is based follow. A few general notes are followed by a discussion of the analysis of the data obtained. Following this, is the table of foods given in volumetric percentage by months. Opposite each date of collection is given the number of specimens which contained food and the number which were found to be empty. The modal, maximum and minimum lengths in millimeters are given next to convey a general idea of the size of the specimens examined. In cases in which no modal length is given the specimens were so scattered or few in number that no distinct mode was discernable from the frequency graph. Of course, in other cases the significance of the mode is directly proportional to the number of variants measured. In plotting these on graphic paper groupings of 4.0 mm. each were used throughout, beginning with 0 to 4 as the first group.

The body of the table in which the various organic substances are arranged in systematic order follows next, with the unidentified materials placed last. The figures for any one month indicate the averages for that collection. They have been reduced in practically all cases to whole numbers because figures closer than 0.5 per cent. have no particular significance, owing to the variation of the estimates and other uncontrollable factors. All such materials present in quantities of less than 0.5 per cent. are indicated simply by a plus sign indicating a mere trace. The general average for the whole year differs slightly from that which would be obtained by averaging the monthly numbers since the original calculations with all their fractional parts have been used because frequently the aggregate number of plus signs was sufficient to form a whole number. This grand average then also was smoothed in a similar manner to the method used for the monthly averages. Here, also, the value of the results is directly proportional to the number of specimens.

The table is followed in each case by a list of annotations amplifying and explaining certain features not expressed in the table itself or its preceding analysis.

Semotilus bullaris (Rafinesque) FALLFISH

Examples of *Semotilus bullaris* ranging from 1.6 to 12.2 cm. in length were taken. Those of the larger size were at once distinguished from *S. atromaculatus* of which a considerable number were taken also, by the black spot at the base of the anterior rays of the dorsal fin, from which the species takes its name. The very small specimens, however, were extremely difficult since most of the adult charactertistics had not yet appeared, and it was only after considerable study that they were separated to our satisfaction. *S. bullaris* is separated from *S. atromaculatus* chiefly by its larger scales and the crowded conditions of the anterior costal scales of the latter which is not apparent in very small specimens of *S. bullaris*. Most of the specimens taken were immature. None below 4.0 cm. were mature while most of those of greater length were sexually developed. Graphs were constructed plotting the lengths with their frequencies. Those below 4.0 cm., which formed the majority, composed a well-defined group forming a single mode as is indicated in Table No. II. No second mode was formed since the larger specimens were too few in number to show any tendency in that direction. The small number of mature individuals suggests that probably the adults run up the stream to spawn. This would be in accordance with observations of this species in various lakes where it is known that the adults spawn in the streams. Fowler ('08) records this species as reaching a length of eighteen inches which is several times the length of our largest specimen.

Judging from the modal lengths of each collection these fish appeared to be chiefly of two-year classes; that is, most of those collected from January to July inclusive were undoubtedly of the spawning season of 1919. In September those of the 1920 spring began to appear in the collections, being by this time large enough to be unable to escape through the meshes of the seine. During the months of March, June, September, November, and December, a few larger individuals probably of greater age were taken.

Analysis of Stomach Contents:—Reference to the accompanying table plainly shows that this species is decidedly insectivorous, since these invertebrates formed 87 per cent. of the entire food of the 242 fish which were found to have been feeding. The plant remains amounting to only 5 per cent. apparently were taken incidentally. In September these remains were found to be present among the food in their greatest quantity (17 per cent.) but this relatively large amount in no way invalidates the conclusion that they were accidentally ingested, because none of the diatoms or algae were found to be plasmolized which would have been the case if any of them had been acted upon by digestive fluids; or if they had been macerated, the alcohol would have completed that action. This, together with the fact that the unidentified debris also amounted to only 5 per cent., suggests that these fish are not bottom feeders, and as they do not have a superior mouth, (Figs. 103 and 111), the inference is that they captured most of their prey as it fell through the water at some point below the surface. It was observed that specimens in the aquarium usually fed in this manner. Assuming this to be the truth, the lack of diatoms and algae would be explained since in the locality where the collections were made these plants must have been taken from the bottom because of the absence of larger plants, brush, etc., to which such growths could adhere and flourish, while the swiftness of the current precludes the existence of pelagic forms. Some of what they took might well have been broken fragments drifting down stream from above which were snapped up in passing. Additional evidence that this species indulged in bottom feeding to only a slight extent is furnished by the fact that not a single grain of sand was found

Table No. II *Semotilus bullaris* Tabulation of Stomach Contents

Date Taken	Jan. 1	Feb. 1	Mar. 14	Apr. 11	May 23	June 13	July 17	Sept. 4	Oct. 4	Nov. 7	Dec. 5	Totals
Number of Full Specimens	101	6	22	24	34	12	4	24	2	2	11	242
Number of Empty Specimens	13	12	23	3	0	0	1	0	0	0	4	56
Modal Length (mm)	30	22	30	32	34	38	...	26	...	...	...	Aver-
Maximum Length	44	36	88	52	48	52	56	44	48	122	72	ages
Minimum Length	16	16	24	20	24	36	44	20	36	28	28	
Diatoms	...	...	...	...	14	...	...	16	...	...	...	02
Filamentous Algæ	...	...	...	...	...	...	...	01	...	...	...	+
Unidentified Plant Remains	...	08	...	...	...	09	...	...	...	...	...	02
Total Vegetable Matter	...	*08*	...	...	*14*	*09*	...	*17*	...	...	...	*05*
Chætopoda	11	...	04	...	05	...	...	...	...	...	...	01
Decapoda	01	...	04	...	...	...	...	...	...	...	...	01
Diplopoda	...	...	...	04	...	...	...	...	...	...	...	01
Larval Ephemeroptera	08	...	...	...	...	...	...	...	...	...	...	01
Larval Plecoptera	11	...	04	...	...	...	...	...	...	...	14	02
Larval Coleoptera	01	...	...	...	...	...	...	...	...	...	...	+
Adult Coleoptera	06	17	39	24	45	33	50	16	100	...	...	30
Larval Lepidoptera	05	...	...	...	...	...	...	...	...	...	...	01
Crysilid of Lepidoptera	01	...	...	...	...	...	...	...	...	...	...	+
Larval Diptera	...	...	...	08	...	...	...	...	...	...	...	01
Adult Diptera	...	...	...	04	01	25	...	...	...	...	36	06
Adult Hymenoptera	...	...	...	10	12	...	...	16	...	...	...	03
Unidentified Insect	30	58	41	50	21	33	50	48	...	100	50	43
Total Insect Remains	*62*	*75*	*84*	*96*	*79*	*91*	*100*	*80*	*100*	*100*	*100*	*87*
Fish	...	...	04	...	...	...	...	...	...	...	...	+
Unidentified Debris	26	17	04	...	02	...	...	03	...	...	...	05

Jan. 1. The crustacean remains consisted of the chela of a *Cambarus* of small size. Among the debris was found a partly digested ctenoid scale, probably from a *Boleosoma*, the only abundant fish of this locality bearing such scales. All the Chætopods were small annelids, allies of *Tubifex*, etc. March 14. The crustacean remains consisted of the eye of a *Cambarus*. The fish had eaten a hydrophylid beetle, and a magot-like larva was among the unidentified insect remains. April. 11. Diplopods were represented by a fragment of a millepede. May 23. One individual had eaten a buffalo fly, two had taken ground beetles and four contained a white paste, together with the hard parts of beetles. The former was presumably the partly digested soft parts of these insects. Sept. 4. An ant was present among the Hymenoptera.

in any stomach, although in several of the other species sand was found quite commonly.

No correlation of feeding habits and size was discerned in any case since all sizes fed on essentially the same types of organisms. The few exceptions noted are attributable simply to mechanical differences due to size. As an example, in March a *Boleosoma* was eaten by a fish 86.5 mm. in length. It is obvious that some of the smaller specimens could not have eaten a *Boleosoma* since many were smaller than the Darter itself. It may be noted here that not a single case of cannibalism was observed in any of the six species studied.

The tabulations of the number of fish found to be empty plainly shows that these fish feed considerably less during the cold months. On February 1, the coldest day on which a collection was made, when ice two inches thick was broken in order to operate the seine, twice as many of the stomachs were found to be empty as those which contained food and of the latter, two-thirds contained very little food.

This species appeared to be nearly free of intestinal parasites and no other kinds were noted among the entire series of 298 specimens. Only ten contained parasitic worms in the alimentary tract. These parasites were distributed as follows:—January, 4; February, 1; March, 4; April, 1. None was found in any succeeding months.

All foods other than insect were present in such small quantities that they cannot be considered important.

It should be noted here also that such bottom forms as the larval Plecoptera and Ephemeroptera were taken only in the colder months when fewer terrestrial insects were available, and the fish were naturally seeking deeper water on account of low temperature at the surface.

Incidentally fourteen specimens of *S. atromaculatus* were examined and it was found that they had partaken of food practically identical to that taken by *S. bullaris*.

Table No. III — *Leusiscus vandoisulus* — Tabulation of Stomach Contents

Date Taken	Jan. 1	Feb. 1	Mar. 14	Apr. 11	May 23	June 13	July 17	Sept. 4	Oct. 4	Nov. 7	Dec. 5	Totals
Number of Full Specimens	31	0	8	81	56	10	19	45	23	11	0	284
Number of Empty Specimens	3	0	0	1	1	0	2	0	3	0	0	10
Modal Length (mm)	58,30	...	...	48,30	52,34	34	42	42,30	34	38	...	Aver-
Maximum Length	64	...	54	64	60	52	56	56	56	56	...	ages
Minimum Length	20	...	30	20	20	24	32	20	28	32	...	
Diatoms	...	...	...	...	...	...	01	01	...	...	...	+
Filamentous Algæ	...	...	...	...	...	...	03	...	...	...	...	+
Total Vegetable Matter	...	...	...	...	...	...	*04*	*01*	...	...	...	+
Chætopoda	...	...	...	01	...	...	...	...	...	...	...	+
Decapoda	...	...	...	01	...	...	...	...	...	...	...	+
Adult Thysanura	01	...	...	...	...	...	...	...	...	...	...	+
Larval Ephemeroptera	28	...	24	...	...	...	...	...	...	...	...	06
Nympth of Odonata	...	...	...	...	...	...	...	01	...	...	...	+
Larval Plecoptera	16	...	...	...	...	...	...	...	...	...	...	02
Larval Trichoptera	...	...	...	...	02	...	...	...	...	...	...	+
Adult Orthoptera	...	...	...	...	01	...	...	...	...	...	...	+
Larval Coleoptera	02	...	08	...	...	...	...	...	...	...	...	02
Adult Coleoptera	13	...	...	38	77	...	21	27	08	...	...	20
Larval Lepidoptera	03	...	...	01	...	...	...	...	...	...	...	+
Adult Diptera	03	...	...	05	...	...	...	...	14	32	...	07
Adult Hymenoptera	...	...	19	02	02	30	05	04	04	04	...	08
Unidentified Insect	33	...	32	51	16	70	70	67	74	64	...	53
Total Insect Remains	*99*	...	*83*	*97*	*98*	*100*	*96*	*99*	*100*	*100*	...	*98*
Arachnida	...	...	05	01	...	...	...	...	...	...	...	+
Mollusca	01	...	...	...	...	...	...	...	...	...	...	+
Unidentified Debris	...	...	12	...	02	...	...	...	...	...	...	02

Jan. 1. A partly digested planarian was found among the debris. The molluscan remains consisted of a single specimen of *Limax*, sp. Among the remains of larval coleoptera was found a Parnid beetle. April 11. The decapod remains consisted of the chela of a crayfish. One specimen had eaten an ant. A single representative of each of the following families was found: Hydrophilidæ, Syrphidæ, and Chalcidæ. May 23. The following families of terrestrial beetles were found in many stomachs: Carabidæ, Elateridæ and Chrysomelidæ, the former two of which were represented by individuals small enough to be swallowed entire, but had suffered from subsequent maceration. Much of the unidentified insect was also very probably the remains of beetles. The Orthoptera was represented by a single small grasshopper. June 13. Most of the Hymenoptera were chalcid flies. July 17. Four maggots were found in one stomach. Sept. 4. Several kinds of insects were present among those entered as unidentified.

Leuciscus vandoisulus Cuvier and Valenciennes
Rosy-sided Dace

The specimens of *Leuciscus vandoisulus* that were collected for this study appeared to be of normal size. Fowler ('08) gives a length of from 1¾ to 3 3/16 inches which compares well with our maximum and minimum of 6.4 and 2.0 cm., (2.11 and 1.27 inches). This species has been recorded as having a maximum length of 5.0 inches. Our series which of course included very young fish, did not include any which reached Fowler's largest. There was no particular difficulty experienced in identifying the mature specimens because of the beautiful rose red streak on the sides brought out in the preservative both on the males and females. The young which did not have this distinctive mark were easily identified by their large gape of mouth and a certain dark pigment along one of the lateral fascia which showed through the skin and scales as a diagonal dark streak from shoulder to tail. (Breder, '20, b). This well served to separate this species from the other twenty-three taken at this locality. Ripe fish about to spawn were taken in May.

At least four of the collections show two distinct modes in the frequency graphs which clearly divides the fishes into two year-classes (Breder '20, a). The group of smaller specimens represents those which hatched in the spring or summer of 1919, while that of the larger fishes were mostly of the 1918 season, a few possibly being referable to 1917. In September, examples of fish hatched in the spring of 1920, entered the collections but so far overlapped those of 1919 as to merely shift the mode a trifle and lower the minimum lengths.

No correlation appeared to exist between size and feeding habits of this species, mechanical limitations alone entering.

Analysis of Stomach Contents:—The food of this species is practically identical with that of the preceding differing only in very minor details. In this species the insects amounted to 88 per cent. and the vegetable content to only a trace, reaching only 4 per cent. in the month of its greatest amount. In these fish the diatoms and algæ also were found in an unplasmolized condition, and the unidentified debris averaged only 2 per cent.

Table No. IV *Notropis procne* Tabulation of Stomach Contents

Date Taken	Jan. 1	Feb. 1	Mar. 14	Apr. 11	May 23	June 13	July 17	Sept. 4	Oct. 4	Nov. 7	Dec. 5	Totals
Number of Full Specimens	26	5	37	40	61	28	27	28	9	16	7	284
Number of Empty Specimens	7	7	33	6	1	0	0	0	0	1	0	55
Modal Length (mm)	38,18	22	38	38,22	38	42,26	42,34	42	42	46,38	42	Aver-
Maximum Length	52	48	52	48	52	52	48	44	44	48	48	ages
Minimum Length	16	16	28	20	32	24	32	32	28	32	40	
Diatoms	...	...	...	20	91	71	58	66	61	59	...	39
Filamentous algæ	...	...	...	...	01	...	26	33	01	01	...	06
Unidentified Plant Remains	...	20	...	...	...	...	...	...	...	...	...	02
Total Vegetable Matter	...	*20*	...	*20*	*92*	*71*	*84*	*99*	*62*	*60*	...	*47*
Unsegmented Worms	...	...	...	00½	01	01	...	...	...	...	...	+
Chætopoda	25	...	31	02	...	02	...	...	...	...	64	13
Larval Ephemeroptera	05	...	03	...	...	...	...	...	...	...	14	02
Nymph of Odonata	...	...	...	01	...	...	...	...	...	...	...	+
Larval Plecoptera	10	...	...	...	...	...	...	...	...	...	08	01
Larval Coleoptera	04	...	...	...	...	...	...	...	...	...	...	+
Adult Coleoptera	...	...	10	13	02	08	12	...	...	...	...	04
Larval Lepidoptera	11	...	...	...	...	...	...	...	...	...	...	01
Unidentified Insect	20	80	56	34	04	14	04	01	38	40	14	28
Total Insect Remains	*50*	*80*	*69*	*48*	*06*	*22*	*16*	*01*	*38*	*40*	*36*	*36*
Acarida	...	...	...	00½	...	...	...	...	...	...	...	+
Unidentified Debris	25	...	...	29	01	04	...	...	...	...	...	04

Jan. 1. Five fish contained parasitic worms. Feb. 1. Five specimens contained very little food, two had taken larval insects and one what appeared to be weed seed. March 14. Seven specimens held very little, one an insect larva and one was fairly full of food. The Chætopods were probably near allies of *Tubifex*. April 11. Five contained very little food, one a staphylinid beetle, while some of the worms eaten were very small. Two fish were the hosts of parasitic worms. The Acarida were represented by a few water mites in one stomach. May 23. Four specimens contained very little, one had an insect larva while two had two and three worms, respectively. Probably some of the algæ was *Voucheria*. One specimen contained sand and silt with what was probably vegetable debris. Many fish were very full. June 13. One had eaten very little. The debris was probably mostly of vegetable origin. July 17. Some of the algal remains were probably *Spirogyra*. Sept. 4. Eight specimens had ingested considerable sand. Most of the algæ was *Spirogyra*. Oct. 4. Two specimens contained sand grains.

The strongly oblique and capacious gape, (Figs. 104, 105, and 112,) suggests that this species is inclined to feed from the surface. This is well borne out by the table of foods, since in all probability the Thysanura were taken while being supported on the surface film. In aquaria it was noted that this cyprinoid tended to keep nearer to the surface than any of its associates.

In the specimen which had taken a larval caddis fly was found a small amount of detritus which was absent from the remaining specimens, 294 having been examined. This suggests that bottom feeding is only occasional. As in *Semotilus*, it is quite evident that the only regular bottom feeding was performed in the winter months with the exception of the above mentioned caddis fly and a dragon fly nymph taken in September. The low temperature and lack of food at the surface probably caused the descent of this species although some food could, no doubt, have been taken at times as it was released from melting blocks of ice as they drifted down stream.

Lighter feeding in winter is not indicated by the number of empty stomachs or their distribution in time, although if this species had been taken in February and December such a condition might have been suggested. Attention is called to the possibility of a semi-hibernation or dormancy, because no specimens were taken on the two collecting days which were most cold.

Notropis procne (Cope) Delaware Minnow

The examples of *Notropis procne* which were collected ranged in length from 1.6 to 5.2 cm. Fowler ('08) gives their lengths as reaching up to 2 11/16 inches which is a little in excess of what our maximum examples showed. It was easily distinguished from any of the other species which we took. However, we carefully scrutinized each specimen in order to exclude *N. bifernatus* which has not been recorded from this region, but has been taken in Maryland, just north of the District.

Five collections show what appears to be a double mode but the overlapping of the extremes is so great that it quite obscures any attempt to read the age of the various groups from such data alone. There is no differentiation of food with the advance in size.

Table No. V *Notropis cornutus* Tabulation of Stomach Contents

Date Taken	Jan. 1	Feb. 1	Mar. 14	Apr. 11	May 23	June 13	July 17	Sept. 4	Oct. 4	Nov. 7	Dec. 5	Totals
Number of Full Specimens	10	0	53	43	28	41	46	12	12	10	10	265
Number of Empty Specimens	1	0	20	5	0	0	0	0	0	0	0	26
Modal Length (mm)	54	...	54,30	26	38	54,34	38	42	42,30	58,30	...	
Maximum Length	60	...	84	56	56	56	64	60	52	68	96	Aver-ages
Minimum Length	28	...	20	20	24	28	32	24	24	24	36	
Diatoms	...	...	...	...	94	05	15	77	33	29	...	25
Filamentous Algæ	...	...	...	...	...	...	27	08	+	38	...	07
Unidentified Plant Remains	...	...	...	...	...	03	06	...	...	...	04	01
Total Vegetable Matter	...	...	...	...	*94*	*08*	*48*	*85*	*33*	*67*	*04*	*33*
Unsegmented Worms	...	...	...	...	+	...	...	...	...	...	...	+
Chætopoda	08	...	01	01	...	...	...	...	...	...	04	02
Larval Ephemeroptera	42	...	06	...	...	...	...	...	...	...	21	07
Odonata Nympth	...	...	05	...	...	...	...	...	...	...	...	+
Larval Plecoptera	10	...	08	...	...	...	...	...	...	...	...	02
Larval Coleoptera	...	...	...	...	...	...	...	...	...	...	02	+
Adult Coleoptera	...	...	04	...	04	30	16	...	21	...	07	08
Larval Diptera	...	...	...	...	...	...	...	...	...	...	02	+
Adult Hymenoptera	...	...	04	...	...	03	02	...	04	...	...	01
Unidentified Insect	40	...	70	36	01	59	32	15	42	33	60	39
Total Insect Remains	*92*	...	*97*	*36*	*05*	*92*	*50*	*15*	*67*	*33*	*92*	*57*
Acarida	...	...	...	...	01	...	...	...	...	...	...	+
Unidentified Debris	...	...	02	63	...	...	02	...	...	...	...	08

Jan. 1. No correlation between size and food eaten could be found in this month's series, or in any of the others. Feb. 14. Very little had been eaten by fourteen specimens, three had taken gomphid nymphs, three had eaten ants, and one contained an unidentified insect larva. April 11. One had taken very little food. Most of the food was found in the posterior part of the intestine; which suggests that it had not been feeding recently, the time of collecting being 1:45 to 5:30 P. M. on a cloudy day. May 23. One specimen had taken very little. Three families of beetles were recognized: Staphylinidæ, Scarabaeidæ, and Chrysomelidæ. A single specimen of Rhynchophora was present. In several cases the chlorophyl from the plants ingested was visible through the thin body walls of small specimens. June 13. One specimen was extremely distended with food. Five contained parasitic worms; two some sand and mud, and one a single specimen of some species of Ichneumonidæ. July 17. One specimen had taken very little and two held three parasitic worms each. Some of the algæ was probably *Spirogyra*. Oct. 4. One held two parasitic worms and another some sand grains. Nov. 7. Three had taken very little food. Dec. 5. Four had eaten very little and one had four parasitic worms. The larval Coleoptera remains consisted of one parnid beetle.

Analysis of the Stomach Contents:—It may be seen at a glance that the feeding habits of this species are somewhat different from those of the two preceding forms. Here the vegetable remains exceed those of the insect, the respective percentages being 47 and 36. Also, the comparatively large amount of sand indicates a bottom feeding habit. In aquaria this was not observed to be especially noticeable, since most of the specimens kept well up in the middle water. The rather subterminal mouth does not suggest that these fish are bottom feeders to a much greater extent than *Semotilus,* although the food points strongly to that conclusion.

The number of empty stomachs and the months in which they were found indicates that this species also feeds less heavily in the winter than at other times.

Notropis cornutus (Mitchill) Redfin

Our specimens of this species varied in length from 2.0 to 9.6 cm. According to Fowler ('08) this species appears to reach a length of about twice that of our largest. Many of our larger specimens were breeding fish. All above 4.0 cm. were mature while all those of less length were juvenile. In the frequency graph this point coincides with the gap or point of greatest depression between two modes when such were distinctly present. Collections in which only one mode was evident a few scattering specimens were always to be found on the other side of this line of demarcation. Obviously there were two year-classes represented here, and the group of smaller specimens was evidently from the spawning of the previous year, while the mature fish had passed through two or more winters. Here we have the same length of time required to reach maturity as was found necessary for *Leuciscus.* Ripe fish about to spawn were taken in May.

No correlation between size and the food taken could be found.

Analysis of Stomach Contents:—This species feeds upon about twice as much insect as vegetable matter. Judging from specimens in aquaria, they seem to be given to rather promiscuous feeding. As observed in captivity, they were noted to rise to the surface with both the force and grace of a trout although they seemed also to be quite adept at securing food from the bottom.

Table No. VI *Rhinichthys atronasus* Tabulation of Stomach Contents

Date Taken	Jan. 1	Feb. 1	Mar. 14	Apr. 11	May 23	June 13	July 17	Sept. 4	Oct. 4	Nov. 7	Dec. 5	Totals
Number of Full Specimens	31	1	7	25	18	4	24	16	21	37	7	191
Number of Empty Specimens	15	1	7	23	2	3	4	0	6	1	4	66
Modal Length (mm)	42, 22	...	...	42. 22	...	...	38	38	38	26	42	Aver-
Maximum Length	48	28	56	48	48	44	44	48	44	48	48	ages
Minimum Length	16	20	16	16	24	24	28	24	20	20	20	
Diatoms	...	...	...	...	55	...	01	90	57	40	...	22
Filamentous Algæ	...	...	...	...	01	...	01	...	01	17	...	02
Unidentified Plant Remains	...	...	...	...	...	...	01	...	...	...	...	+
Total Vegetable Matter	...	...	...	...	*56*	...	*03*	*90*	*58*	*57*	...	*24*
Chætopoda	10	...	...	...	...	...	...	...	...	22	04	04
Larval Ephemeroptera	03	...	...	...	...	...	...	...	...	...	...	+
Larval Plecoptera	11	...	28	...	...	...	...	...	...	...	14	05
Larval Trichoptera	...	...	...	16	...	...	...	...	...	...	14	02
Larval Coleoptera	...	...	...	...	...	...	...	...	...	...	10	01
Adult Coleoptera	02	...	...	04	22	...	...	09	04	...	...	04
Larval Lepidoptera	...	...	22	...	...	...	...	...	...	...	...	02
Adult Diptera	...	...	...	04	...	...	...	...	...	...	...	+
Adult Hymenoptera	01	...	...	...	...	...	...	...	...	...	...	+
Unidentified Insect	53	...	35	64	22	100	86	01	33	21	58	43
Total Insect Remains	*70*	...	*85*	*88*	*44*	*100*	*86*	*10*	*37*	*21*	*96*	*57*
Arichnida	01	...	...	...	...	...	...	...	...	...	...	+
Unidentified Debris	19	100	15	12	...	...	11	...	05	...	...	15

Jan. 1. Three contained unidentified insect larvæ and among the debris was a worm which evidently was not an annelid. March 14. Two specimens contained parasitic worms and one sand grains. April 1. Eight specimens contained very little; one an aquatic beetle; five contained parasitic worms; two unidentified insect larvæ. One fish was blind in the left eye. May 23. One contained very little; five contained parasitic worms; among the diatomaceous remains were noted a very few desmids. (Not listed in the table.) June 13. One contained very little food. July 17. Six contained very little food and two contained parasitic worms. Sept. 4. Six contained parasitic worms; one very little food; one sand grains. Oct. 4. One held parasitic worms and four unidentified insect larvæ, and three held sand grains. Nov. 7. Three contained sand grains. Dec. 5. One contained very little and one contained parasitic worms. Some of the unidentified insect remains was probably Coleoptera.

FIG. 103. *SEMOTILUS BULLARIS*
Standard length 12.0 cm.

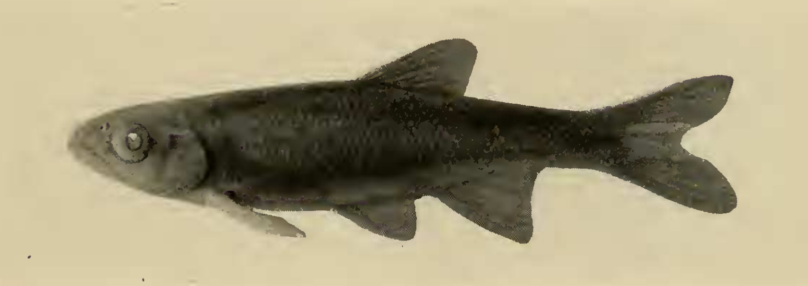

FIG. 104. *LEUCISCUS VANDOISULUS*
Standard length 6.3 cm.

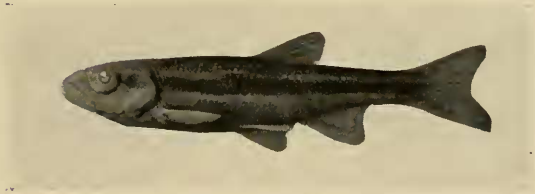

FIG 105. *LEUCISCUS VANDOISULUS*, imm.
Standard length 3.8 cm.

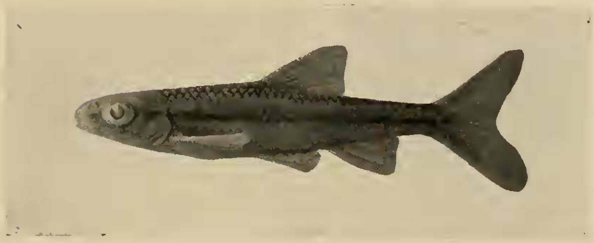

FIG. 106. *NOTROPIS PROCNE*
Standard length 4.6 cm.

FIGS. 103-106. FISHES FROM OXON RUN

FIG. 107. *NOTROPIS CORNUTUS*
Standard length 9.0 cm.

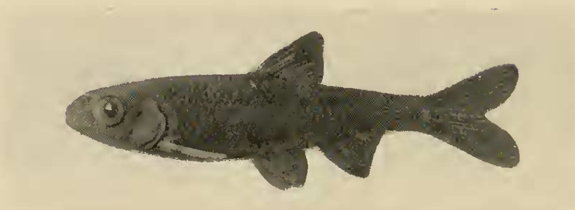

FIG. 108. *NOTROPIS CORNUTUS*, imm.
Standard length 5.3 cm.

FIG. 109. *RHINICHTHYS ATRONASUS*
Standard length 3.9 cm.

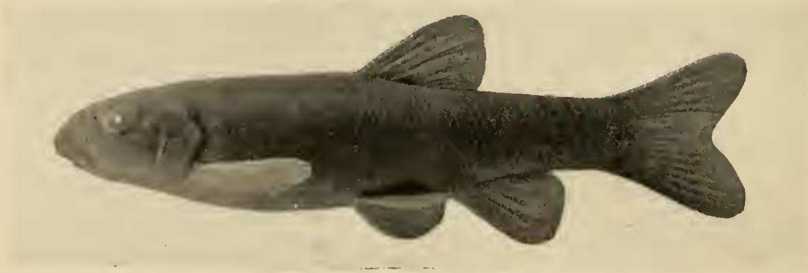

FIG. 110. *EXOGLOSSUM MAXILLINGUA*
Standard length 6.3 cm.

FIGS. 107-110. FISHES FROM OXON RUN

The percentage of empty stomachs and the months in which they occurred, in this case also, indicates a cessation of active metabolism during the cold season.

Rhinichthys atronasus (*Mitchill*) BLACK-NOSED DACE

This readily recognized species required close examination only to prevent the possibility of confusing it with *R. cateractæ,* which, however, was not taken in any of our collections. Our specimens varied in length from 1.6 to 5.6 cm. Fowler ('08) found his maximum to be 3½ inches, which is somewhat larger than ours. The smallest mature fish had a length of 3.0 cm. although a few above that size were immature. The two collections showing double modes on the frequency graphs presented the point of greatest depression between them at approximately the 3.0 cm. point. However, the overlapping of the year-classes was so great that very little information could be deduced therefrom. Nothing except the fact that more than one year-class was present could be satisfactorily determined.

Analysis of Stomach Contents:—This species appears to be intermediate in feeding habits between *Semotilus* and *Leuciscus* on one hand and the two species of *Notropis* on the other, the vegetable and insect remains appearing as 24 and 61 per cent. respectively. The unidentified debris amounted to a considerable quantity, constituting the remaining 15 per cent.

The number of fish which were not feeding before the time of capture roughly suggests a lighter feeding in the colder months.

This species was the most heavily infested with intestinal parasites, although the fish seemed to show no ill effects from the presence of these worms since they were uniformly fat and healthy in appearance. In all, 22 examples out of the 257 specimens that were examined contained one or more parasites.

The vegetable remains were found to be almost exclusively in an unplasmolized state.

Specimens in the aquarium appeared to feed almost indifferently from either the bottom or middle of the tank, and occasionally rose to the surface.

Table No. VII *Exoglossum maxillingua* Table of Stomach Contents

Date Taken	Jan. 1	Feb. 1	Mar. 14	Apr. 11	May 23	June 13	July 17	Sept. 4	Oct. 4	Nov. 7	Dec. 5	Totals
Number of Full Specimens	0	0	2	3	9	20	9	4	1	9	. 2	59
Number of Empty Specimens	3	0	6	1	1	2	0	1	0	1	1	16
Modal Lengths (mm)	...	...	...	...	30	30	38	38	...	42	...	Aver-
Maximum Length	44	...	52	52	48	58	56	44	25	60	64	ages
Minimum Length	28	...	24	20	24	28	32	36	...	24	36	——
Diatoms	...	...	...	...	26	05	11	37	...	...	...	08
Filamentous Algæ	...	...	...	...	+	...	...	...	...	...	...	+
Unidentified Plant Remains	...	...	...	...	...	...	55	...	...	...	...	07
Total Vegetable Matter	...	...	...	...	*26*	*05*	*66*	*37*	...	...	...	*15*
Chætopoda	...	...	50	...	22	57	...	13	...	23	100	30
Adult Coleoptera	...	...	...	...	08	...	...	...	...	...	...	01
Unidentified Insect	...	...	50	67	22	33	12	50	...	77	...	34
Total Insect Remains	...	...	*50*	*67*	*30*	*33*	*12*	*50*	...	*77*	...	*35*
Fish Ova	...	...	...	...	...	05	...	...	...	...	...	+
Unidentified Debris	...	...	...	33	22	+	22	...	100	...	...	20

March 14. Two specimens contained parasitic worms. The annelids were possibly *Tubifex,* or an allied species.

June 13. The fish eggs were represented by the ova of some small fish, probably a cyprinoid. In the same stomach were also several other ovate bodies, which were probably parasitic cysts. Two other stomachs contained parasitic worms. Some of the unidentified debris was probably of vegetable origin and some of the unidentified insect remains was probably Coleoptera.

July 17. One contained very little food. Some of the debris was probably of vegetable origin. In two stomachs there was sand in quantity equal to that of the food.

Sept. 4. Three contained sand.

Nov. 7. A larva was among the unidentified insect remains.

Dec. 5. One of the worms was a *Lumbricus.*

Judging from the relative frequency of Chætopods, Mayfly, and Stonefly larvæ, these fish feed more frequently from the bottom in the colder months, in a manner comparable to the behavior of the other species.

Exoglossum maxillingua (Le Sueur) CUT-LIPS

This unique and striking species presented no difficulty to identification in any way, the peculiar three-lobed mandible being entirely sufficient to at once isolate the species. The lengths of the specimens of our series varied from 2.0 to 6.4 cm. Fowler's ('08) maximum or 4⅞ inches (12.38 cm.) was about twice that of ours, although many of the latter were adult and in breeding condition. This cyprinoid has been recorded as reaching a length of 6.0 inches (15.24 cm.). The smallest mature fish was 4.3 cm. and the largest immature specimen was 5.8 cm. This excessive overlapping of the year-classes together with the unfortunate paucity of the collection precluded drawing of any conclusions as to age.

Analysis of Stomach Contents:—Something decidedly different in the food of this species might be expected judging from the peculiar formation of the lips, (Figs. 110 and 116). However, this was not found to be so, as practically all of the food of this species was similar to that taken by the others. The large amount of debris and vegetable matter suggests that these fish were primarily bottom feeders. In the aquarium, this was observed to be the case, the specimens for the most part poking around in little nooks and crannies among the rocks and negotiating with difficulty all but the smallest particles of food. However, they were seen to rise occasionally to the surface as small particles of food were descending through the water.

In this case, also, feeding was less heavy during the winter season. In those specimens which contained diatoms, the diatoms appeared partly digested.

DISCUSSION

Comparison of Foods:—Table No. VIII shows the foods of each species for the year side by side to facilitate comparisons.

Table No. VIII

Showing averages of foods taken by each species for entire collection
(Comparison by percentage)

FOOD	*Semotilus*	*Leuciscus*	*N. procne*	*N. cornutus*	*Rhinichthys*	*Exoglossum*
Diatoms	02	+	39	25	22	08
Filamentous algæ	+	+	06	07	02	+
Unidentified plant remains	02	—	02	01	+	07
Total vegetable matter	*05*	+	*47*	*33*	*24*	*15*
Unsegmented worms	—	—	+	+	—	—
Chætopoda	01	+	13	02	04	30
Decapoda	01	+	—	—	—	—
Diplopoda	01	—	—	—	—	—
Adult Thysanura	—	+	—	—	—	—
Larval Ephemeroptera	01	06	02	07	+	—
Odonata nymph	—	+	+	+	—	—
Larval Plecoptera	02	02	01	02	05	—
Larval Trichoptera	—	+	—	—	02	—
Adult Orthoptera	—	+	—	—	—	—
Larval Coleoptera	+	02	+	+	01	—
Adult Coleoptera	30	20	04	08	04	01
Larval Lepidoptera	01	+	01	—	02	—
Crysilid Lepidoptera	+	—	—	—	—	—
Larval Diptera	01	—	—	+	—	—
Adult Diptera	06	07	—	—	+	—
Adult Hymenoptera	03	08	—	01	+	—
Unidentified insect	43	53	28	39	43	34
Total insect	*87*	*98*	*36*	*57*	*57*	*35*
Acarida	—	—	+	+	—	—
Arachnida	—	+	—	—	+	—
Mollusca	—	+	—	—	—	—
Fish	+	—	—	—	—	—
Fish ova	—	—	—	—	—	+
Unidentified debris	05	02	04	08	15	20

The table clearly indicates that all of the species are rather insectivorous. Hymenoptera and Diptera were represented mostly by various minute chalcid flies and midges. Lepidoptera were represented by the larvæ of Geometridæ. All of the insects with few prominent exceptions were terrestrial species which evidently had fallen into the water.

Table No. IX shows in still more epitomized form to what degree each species was carnivorous. The species have been arranged in this table with the most carnivorous coming first. A superficial examination of this table no doubt would suggest to

Table No. IX

Showing degree to which each species is carnivorous
(Comparison by percentage)

SPECIES	Animal	Vegetable plus debris	Insect	Other animal	Vegetable	Debris
Leuciscus	98	02	98	trace	trace	02
Semotilus	90	10	87	03	05	05
Exoglossum	65	35	35	30	15	20
Rhinichthys	61	39	57	04	24	15
N. cornutus	59	41	57	02	33	08
N. procne	49	51	36	13	47	04

the reader that *N. procne* was decidedly vegetarian, the others somewhat so, but to a lesser degree, progressing upward toward *Leuciscus* which shows only 2 per cent. of vegetable matter and debris combined, for the whole year.

However, since most of the vegetable matter was found to have been undigested and all of these species have a short digestive tract and decidedly raptorial pharyngeal teeth, it seems unlikely that *N. Procne* or any of the other species are intentionally vegetarian. It must be noted, however, that in the case of *N. procne* the pharyngeal teeth present a greater grinding surface than in any of the other species, a few of the teeth being simply obliquely truncated cylinders. (Fig. 119).

The lack of vegetable matter in *Leuciscus* and *Semotilus* is easily explained by assuming that they feed above the bottom, as was pointed out in the individual treatments, pages 301 and 295 respectively. Also, the presence of considerable vegetation in the stomachs of *Exoglossum* and *Rhinichthys* may be explained by their known habit of nosing around near the bottom. All considerations point respectively to such habits of these four species: the food, the structure of the mouth, and the habits as observed in the aquarium.

However, in the case of *N. cornutus* and *N. procne* it is another matter. The trout-like grace of *N. cornutus* in no way suggested a typical bottom feeding fish, although a relatively large amount of plant and vegetable debris was found in this species.

Table No. X

Specimens containing no food by months
(Comparison by percentage)

SPECIES	January	February	March	April	May	June	July	September	October	November	December
Semotilus	11	66	51	11	00	00	20	00	00	00	25
Leuciscus	09	—	00	01	02	00	09	00	11	00	—
N. procne	22	58	47	13	02	00	00	00	00	06	00
N. cornutus	09	—	27	10	00	00	00	00	00	00	00
Rhinichthys	32	50	50	46	10	43	14	00	22	03	36
Exoglossum	100	—	75	25	10	09	00	05	00	10	33

In the case of *N. procne,* the only suggestions of bottom feeding were the very slightly inferior mouth and the rather prominent grinding surfaces of the pharyngeal teeth.

These considerations taken as a whole are not convincing that these fish are partly vegetarian. The impression left by this study was that most if not all of the vegetable matter was ingested accidentally along with the invertebrates which are usually associated with diatoms and filamentous algæ. The presence of these plants in such quantities can be explained by the fact that peristalsis in these fishes depends largely upon the mechanical action of forcing the food backwards as more food is eaten and consequently digestion is rather a slow process. Owing to this, the presence of the silicon and cellulose covered cells, of diatoms and algæ, for a more or less protracted period would be expected. Furthermore even the chitonous parts of insects can be discerned at times even in the excrement of these fishes.

In view of the fact that none of the vegetable matter seemed to have been acted upon by digestive juices, with the possible exception of diatoms in some specimens of *Exoglossum* previously noted (page 307), it seems to be an unwarranted conclusion from the examination of the stomachs of these fishes that they are vegetarian, or derive any perceptible amount of nourishment from vegetation ingested.

These fishes appear to be very adaptable to changing conditions of food and feeding. In an aquarium they take anything and everything that is given to them, living or dead, both the food which might possibly have been taken in their native haunts and that which it would have been impossible for them to secure under ordinary conditions, i.e., unnatural foods, such as boiled egg, shredded wheat, cooked meat, boiled potatoes, et cetera.

It is easily demonstrated by means of simple experiments that these minnows will snap at any small particle alighting upon the surface of the water, or settling to the bottom. Whether or not the particle is ingested seems to depend upon its physical properties. To the fish it seemed to be immaterial whether one kind of food or another was presented provided it was of proper size.

"It seems likely to be a general rule," Forbes has written, ('80), "that a fish makes no more than a *mechanical* selection from the particles of food accessible to it, taking almost indifferently whatever edible things the water contains which its habitual range and its peculiar alimentary apparatus enables it to appropriate, and eating of these in about the ratio of their relative abundance and ease with which they can be appropriated at any time and place." The positive identification, therefore, of the different constituents of the food is of small importance when carried beyond a certain point.

The following tabulation seems to include all factors directly concerned with the act of taking food.

EXTRA ORAL

I. Habitat of food.

A. Geographical distribution.
The *ranges* of the food and feeder must overlap. This is necessary for "B" to be possible.

B. Exact, or local position.
The exact local habitats of the food and feeder must overlap and finally the individual feeder, and food unit must be in proximity.

II. Size and condition of food.

A. Limitations.

Upper. Too large to be swallowed and unsuitable for nibbling into small pieces.

Lower. Too small, or well concealed to be perceived by any of the sense organs.

INTRA ORAL

I. Tactile and taste reactions.

A. Tactile limitations.

Upper. Hard, sharp, rough, unmasticatable.

Lower. Soft, flocculent, "melting in mouth." Such food is not rejected intentionally, but most of it usually escapes through the operculum.

B. Taste seems to be unimportant since strongly medicated food only is rejected, and then not always.

Table No. X showing the percentages of empty stomachs for the various months, which by comparison with Table No. I demonstrates lighter feeding for all species during the three coldest months, January, February, and March. In February, only three of the species were represented in our collections which suggests hibernation or a secretive habit during the extreme cold weather. There appears to be no cessation of feeding in any case during the spawning season which in all species was indicated as extending from sometime in April to well into the summer.

Little can be said of the high percentage of empty stomachs in the series of *Rhinichthys* in June since it was composed of only seven specimens.

The general feeding habits of these six species appears to be remarkably similar even as much, or more so, than their anatomical structures. It is rather striking that so many members of the same family of fishes should become suitably adapted for survival in the same localities and still retain their specific identity, although in many cases the young were difficult to differentiate. It seems that all fill practically the same ecological niche and very likely we have here a case of intra-family convergence, rather than divergence from a recent common prototype.

Comparison of Alimentary Tracts

On the whole, there is no vast difference between the alimentary structures of the six species under consideration. However, the minor details vary considerably as shown by the dissections, (Figs. 111-116).

In making these dissections, the body wall of the left side was removed by cutting it through along a median line from the vent forward to a point just posterior to the cardiac cavity, from whence it was passed diagonally upward to a point dorsal of the pharingeals, thence following back just ventrally of the gonads to the vent. In this way, only the visceral cavity was laid open, the heart, gonads and air bladder and kidneys remaining hidden. Two perpendicular cuts were made; one above, and one below the oral cavity extending from the snout to the opened visceral cavity. Between these two cuts, all substance was removed down to the median plane, thus showing the mouth and pharynx in true cross section. In making the semi-diagramatic sketches all unnecessary detail was omitted for the sake of clarity. Thus the structures above and below the buccal cavity are indicated simply by conventional cross-hatching, as is likewise the pelvic girdle.

The intestine, in all cases a simple tube containing a single sigmoid flexure, was spread out somewhat. That is, the forward arm was drawn down and the posterior one upward. By simply swinging them up and down respectively to a nearly horizontal position and allowing their distal ends to act as fulcra, the normal location of the parts can be found. The forward arm would thus lie to the right and the posterior two to the left, one above the other. The liver with its two lobes drops curtain-like to either side of the intestine. Their derangement has been trivial, but slightly different in most of the sketches in order to show the parts to their best advantage.

The representation of all mesentary membranes and fat has been omitted in order that the details which the drawings were designed to show might not be obscured. Lettering of the parts also has been omitted since the shape and locations of the organs together with the descriptive text following is sufficient explanation.

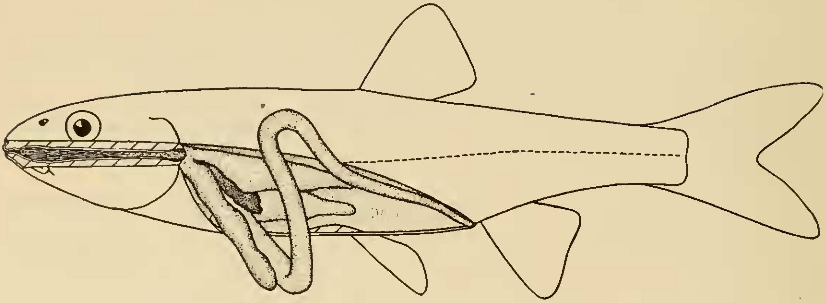

FIG. 111. *SEMOTILUS BULLARIS*
Standard length 12.0 cm.

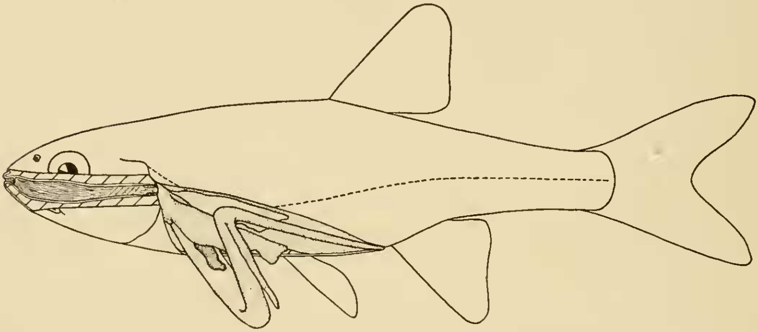

FIG. 112. *LEUCISCUS VANDOISULUS*
Standard length 6.3 cm.

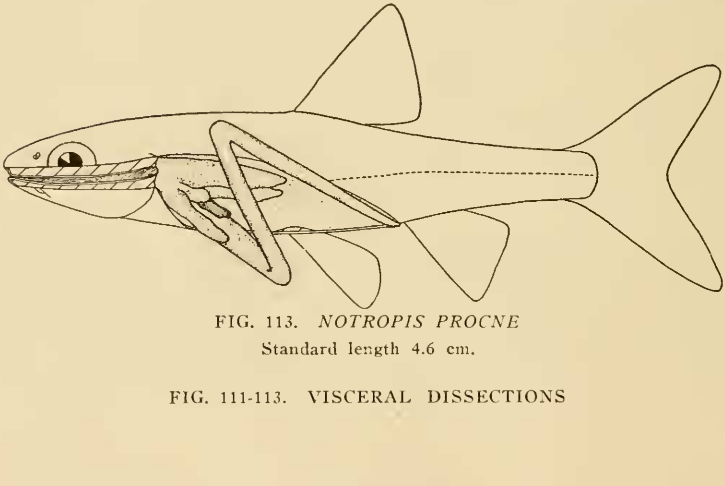

FIG. 113. *NOTROPIS PROCNE*
Standard length 4.6 cm.

FIG. 111-113. VISCERAL DISSECTIONS

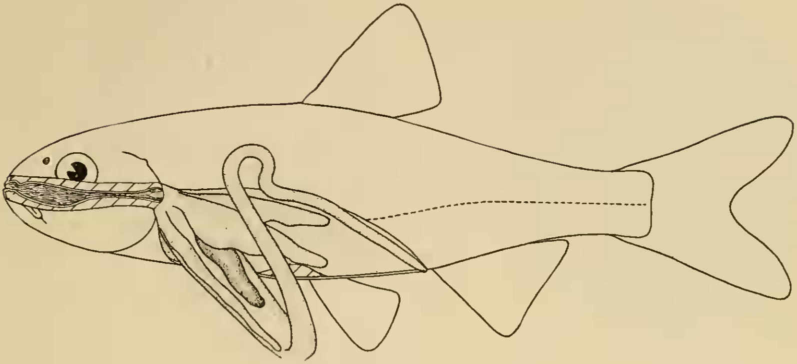

FIG. 114. *NOTROPIS CORNUTUS*
Standard length 9.0 cm.

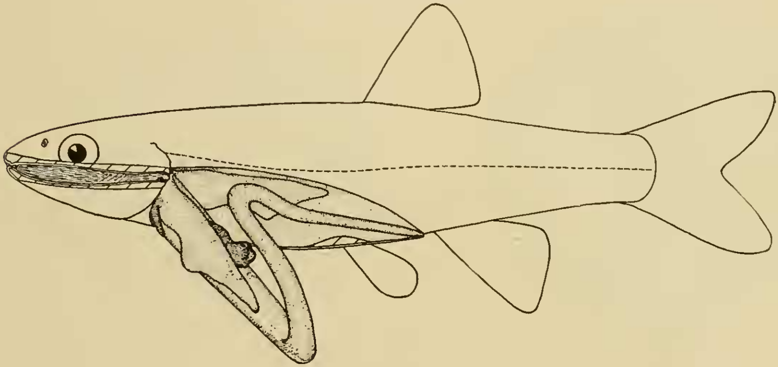

FIG. 115. *RHINICHTHYS ATRONASUS*
Standard length 3.9 cm.

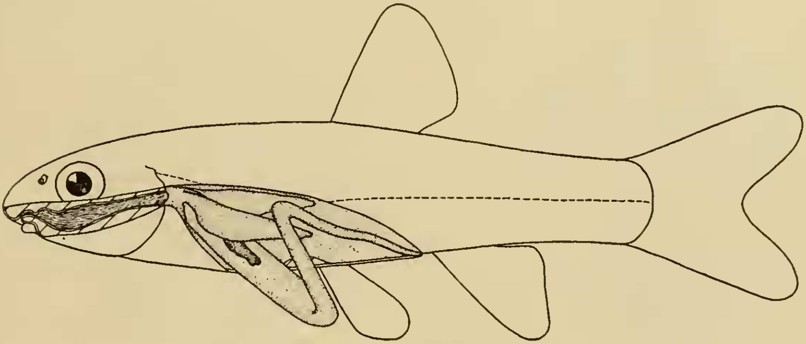

FIG.116. *EXOGLOSSUM MAXILLINGUA*
Standard length 6.3 cm.

FIGS. 114-116. VISCERAL DISSECTIONS

For those readers who are not familiar with the internal anatomy of this group of fishes, it should be mentioned that the stomach is simply the widened anterior arm of the tube extending from gullet to vent, while the posterior portions are considered as intestine. The two-lobed liver (shown by light stippling) is attached to the anterior end of the stomach and the spleen, in all cases a small body (shown by dark stippling) is attached further back. The gall bladder is embedded in the liver and not shown. The pancreas in all cases (also shown in light stippling) lies ventrally to the stomach and it is bound to it with mesentary and is so embedded in fatty tissue that it is hard to differentiate. In all cases, except one, the point of attachment to the stomach wall was at its forward end. In *Leuciscus*, it was apparently attached at the first bend of the sigmoid flexure. However, this is a debateable point and in reality it may have been attached similarly to the others, although the drawing was made as shown only after many specimens were opened.

The structure of the mouth, its inclination and general conformation, are here, as in many other groups of animals, a very fair index to the food and feeding habits. The only species in which the mouth can be considered properly other than terminal are *Exoglossum*, *Rhinichthys* and *Notropis procne*. However, in the latter two, the mouths are very nearly terminal. The buccal cavity is much alike in all of them, being lined with an epithelium of the same general structure throughout. The most pronounced variation in this respect is in the odd formation of the mandible of *Exoglossum* which is so modified that it is divided into three lobes, the central one alone pressing firmly to the upper jaw. (Fig. 116).

There is some similarity in the pharyngeal teeth in all of the species. The comparative drawings show that the greatest difference in number of teeth between any two species is three. Most of the teeth are decidedly raptorial, with small grinding surfaces. The greatest variation is seen in *N. procne* in which some of the teeth are blunt and flat across the end with a fairly well developed grinding surface.

It should be noted here that the teeth were held in various positions to show the shape and number of teeth to the best

FIG. 117. *SEMOTILUS BULLARIS*
Standard length 5.5 cm.

FIG. 118. *LEUCISCUS VANDIOSULUS*
Standard length 5.7 cm.

FIG. 119. *NOTROPIS PROCNE*
Standard length 4.9 cm.

FIG. 120. *NOTROPIS CORNUTUS*
Standard length 7.6 cm.

FIG. 121. *RHINICHTHYS ATRONASUS*
Standard length 4.4 cm.

FIG. 122. *EXOGLOSSUM MAXILLINGUA*
Standard length 3.9 cm.

FIGS. 117-122. PHYRANGEAL TEETH
Diameter of black disc = 1. cm.

FIG. 123. *SEMOTILUS BULLARIS*
Standard length 4.2 cm.

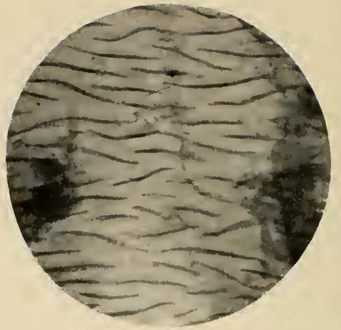

FIG. 124. *LEUCISCUS VANDIOSULUS*
Standard length 4.0 cm.

FIG. 125. *NOTROPIS PROCNE*
Standard length 39 cm.

FIG. 126. *NOTROPIS CORNUTUS*
Standard length 4.0 cm.

FIG. 127. RHINICHTHYS ATRONASUS
Standard length 4.0 cm.

FIG. 128. *EXOGLOSSUM MAXILLINGUA*
Standard length 4.0 cm.

FIGS. 123-128. INTESTINAL WALLS. 28X

advantage in each case.[2] This causes foreshortenings of the supporting pharyngeal bones in various ways, depending upon the angle from which they were viewed. In all cases the pharyngeal bones must bear the same relation to each other in order to accomplish their purpose of masticating the food, but their shapes depend upon the correlated differences of other related anatomical parts.

The stomach, or first arm of the digestive tract, is very similar in all cases, being a simple, nearly straight tube capable of considerable distention, and normally extending to a point slightly past the pelvic girdle. At its anterior end, the liver and pancreas are attached, except in *Leuciscus* in which the latter appears to be attached to the second flexure of the tube, as previously noted, although when the disarranged viscera are re-assembled it seems probable that this organ may be attached to either or both points since they are appressed closely in life. In this position, what appears to be the free end of the pancreas is brought in apposition to a possible point of attachment similar to that of the organ in the other species. In *Rhinichthys* and *Exoglossum* the pancreas appears to be reduced to a small, almost indistinguishable mass. The liver on the left side extends forward of the digestive tract in life and infolds it. The spleen is practically identical in all of the species, except for size and shape, both of which seem to be quite variable in individuals.

The differences in length of the alimentary tracts are too small to be used as an index of food habits. However, the two species of the single genus *Notropis* have the longest tracts. In the case of *N. cornutus* the tube has various curves and bends while that of *N. procne* is made up of three rectilinear sections. *Semotilus* and *Rhinichthys* follow in the order named and *Leuciscus* and *Exoglossum* possess the shortest digestive tracts. The lengths of all are characteristic of carnivorous fishes.

Heinrich Rathke ('24) recognized folds on the intestinal walls of certain European Cyprinoids similar in a general way to those of these species, illustrated by (Figs. 123-128). His list includes *Cyprinus gobio, C. jesus, C. aspius, C. vimba,* and *C. caras-*

[2] The accompanying wash drawings were modified from line drawings made through the camera lucida applied to a low power microscope. The teeth were removed carefully and cleansed, after which they were placed on a block of black parafin, which held them in any desired position and formed a contrastive background.

sius. Our figures of the intestinal walls of *Leuciscus*, *N. cornutus*, and *N. procne* appear to represent one type of folds which under low magnification give an effect somewhat similar to that of the herring-bone weave of cloth. These evidently are the "Zickzack falten" of Rathke. *Rhinichthys* and *Exoglossum* represent another type in which the folds anastomose to a great extent. These folds can be traced for a considerable distance along the top of the ridges without coming to a blind end. This is markedly different from the short, straight, or curved folds of the former three. *Semotilus* represents a still different formation. Here the ridges for the most part are short and heavy, and in many instances they are branched but are not anastomosing in any sense of the word. While these absorptive folds fall into three general groupings, each is distinctive and would serve as a character separating at least these six species.

Each of the figures[3] (123-128) represents a small piece of the intestinal wall taken from a point just posterior to the second angle in the modified sigmoid flexure of the intestinal tract. All of these sections were taken from as nearly similar places as possible and from specimens of about the same size in order to make as close comparisons as desirable.

Thus it is seen that the similarity of these six species extends to their alimentary structures and food. This fact, as previously pointed out, furnishes an illustration of the well-known principle that organisms living in the same environment and under similar conditions tend to develop similar habits and converge in details of their anatomical structures. It seems unlikely that this similarity is due to a divergence from a single ancestral type since these fishes are coexistant in the same locality and subject to the same conditions.

Fish Cultural Significance of These Cyprinoids

By study of the accompanying tables, listing the foods of the six species dealt with in this paper, the conclusion is drawn that these species, at least while they are young, will not destroy the

[3] The photographs are not all that could be desired, since it was found to be impracticable to thoroughly remove the mucus without destroying the ridges. However, the usefulness of the illustrations is not impaired. Alcoholic specimens were used. After the material had been cleansed as well as possible the pieces were immersed in glycerine to clear the tissue a trifle. The photomicrographs were taken with the aid of an Edinger projector, owned by the Bureau of Fisheries.

young of important food and game fishes. However, it is pointed out that insects and other small animals enter into the diet of all small fishes to a certain extent, and in so far as they do, therefore, these minnows must compete with all other fishes of a similar size and habitat. Nevertheless, it is difficult to overestimate the importance of these cyprinoids to fish culture. No doubt continued success in the cultivation of basses, crappies, and other species in ponds might be greater if suitable food could be provided for the growing fish and thus check their well-known cannibalistic tendencies. Similar difficulties in stocking streams with the various salmonoids might be overcome to a large extent by providing them with minnows for food.

All of these cyprinoids are not of equal value in practice and due regard for their variations in habit must be taken into consideration. For instance, if a stream is found to be suitable in every way for the introduction of trout, except that it is deficient in natural food, the deficiency might be overcome by introducing some of the smaller species of cyprinoids, such as *Exoglossum maxillingua*, or *Rhinichthys atronasus*, which are found in clear, rather swift streams. Other species are better adapted to a lacustrine habitat, such as *Semotilus bullaris*, or *S. atromaculatus*. In view of the fact that *S. bullaris* is predatory and sometimes reaches a length of thirteen inches and a weight of a pound or more, this species should be introduced with caution.

Since very little has been recorded concerning the rate of growth of these cyprinoids, success in propagating them in large quantities for fish food is problematical. It is known that some of the species will spawn in aquaria and that the young when reared with small tropical fishes will become adapted to the warm water conditions necessary for the latter. This suggests a method of procedure in stocking a pond with minnows, but the details of the experiment must be worked out for each species under local conditions.

There is no reasonable doubt that a pond may be stocked successfully with minnows provided that they are suitable. Brood stocks should be available in many places since these minnows are widely distributed and generally easily captured with a small seine. The suitability of a species selected for introduction will depend, of course, upon the similarity of its natural habitat to

Table No. XI — List of Species Taken at Oxon Run During 1920

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Sept.	Oct.	Nov.	Dec.	Totals
1. *Lampetra wilderi*, J. & E. ..... (s)	0	1	0	0	0	0	1	0	0	0	1	3
2. *Catostomus commersonii* (Lac.) (s)	0	0	2	0	1	17	4	8	0	0	6	37
3. *Catostomus nigricans*, Le S. (m, s)	1	4	1	0	20	0	5	2	4	3	2	16
4. *Erimyzon sucetta oblongus* (Mitch.) (s)	1	1	0	0	2	0	2	0	0	0	1	5
5. *Hybognathus nuchalis*, Agassiz ..	0	0	0	0	0	0	0	0	0	2	0	2
6. *Pimephales notatus* (Raf.)	0	0	0	0	0	0	0	0	0	2	1	3
7. ***Semotilus bullaris*** **(Raf.)**.........	114	18	45	27	34	12	5	24	2	2	15	298
8. *Semotilus atromaculatus* (Mitch.)	1	1	6	1	0	0	2	0	1	1	0	13
9. ***Leuciscus vandoisulus, C. & V.*** ...	33	0	8	82	57	10	21	45	26	11	0	294
10. *Abramis crysoleucas* (Mitch.)	2	0	0	0	0	0	0	0	0	0	0	2
11. ***Notropis procne*** **(Cope)**..........	33	12	70	46	62	28	27	28	9	17	7	339
12. *Notropis whipplii* (Girard)...(s)	1	0	0	0	0	0	0	0	2	0	0	3
13. *Notropis analostanus* (Girard)...	0	0	4	3	0	1	26	16	10	3	25	88
14. ***Notropis cornutus*** **(Mitch.)**.......	11	0	73	48	28	41	46	12	12	10	10	291
15. *Ericymba buccata*, Cope	0	0	0	0	0	0	0	1	1	0	0	2
16. ***Rhinichthys atronasus*** **(Mitch.)**...	46	2	14	48	20	7	28	16	27	38	11	257
17. ***Exoglossum maxillingua*** **(Le Sueur)**	3	0	8	4	10	22	9	5	1	10	3	75
18. *Anguilla rostrata* (Le Sueur) (s)	0	1	0	0	0	0	0	0	0	0	1	2
19. *Fundulus diaphanus* (Le Sueur)..	Many specimens seen throughout the year											
20. *Lepomis auritus* (Linn.) ......(s)	0	0	2	0	0	0	0	1	1	1	1	6
21. *Eupomotis gibbosus* (Linn.) ..(s)	1	2	2	7	8	0	0	0	4	0	0	8
22. *Micropterus salmoides* (Lac.) (s)	0	0	0	0	0	0	2	0	0	0	0	2
23. *Boleosoma olmstedi* (Storer)	Very abundant throughout the year											

(s)—Small examples only. (m)—Medium sized examples. Certain species were counted and part returned to the stream, which accounts for the apparent discrepancy between the sum of the monthly numbers as shown, and the total, because the latter only includes preserved material.

that into which it will be introduced. Success may not be obtained by stocking ponds with species taken from swift, clear streams, unless, as suggested, the young are hatched and reared under pond conditions, or otherwise properly acclimatized.

It seems desirable to know,

(1) the spawning time, habits and place, in order that comparisons can be made between them and those of the species which will subsist on the minnows. It is obviously desirable to arrange conditions in such a way that the young fish under cultivation will find a supply of young minnows at the time when they are most needed; also

(2) how prolific each species of minnows is and length of time required to mature. However, certain factors, such as good protection to the eggs, etc., might compensate for small numbers; and

(3) the natural conditions under which the minnows live, so that these conditions may be reproduced as nearly as possible and thus assure a continuous supply.

No doubt, many natural ponds which have become over-run with chubs or other species of minnows because of their rapid growth, or because they are able to subsist better on the existing food supply to the exclusion of more desirable species, such as brook trout, could be made a valuable asset to the fish culturist if properly manipulated. The young of all of these cyprinoids are excellent and acceptable food for the young of all piscivorous fishes and if economical ways are developed for handling them, another natural resource may be developed. In all cases it is presupposed that all primary factors will be under the control of the fish culturist. If chubs are to be introduced into ponds when young, they should not be left to reach a large size and their introduction therefore, should depend upon the ease with which they may be removed, i.e., small ponds may be found more effective. Minnows seem to thrive best in streams or ponds where the banks are grown with overhanging vegetation which supports an abundance of insect life. If they are introduced into similar places where they will find their natural food in abundance it is unlikely that they will prey upon the eggs or young of other fishes.